Bars and galaxy interactions in the Illustris simulation

Nicolas Peschken

with E. Lokas

Nicolaus Copernicus Astronomical Center, Warsaw

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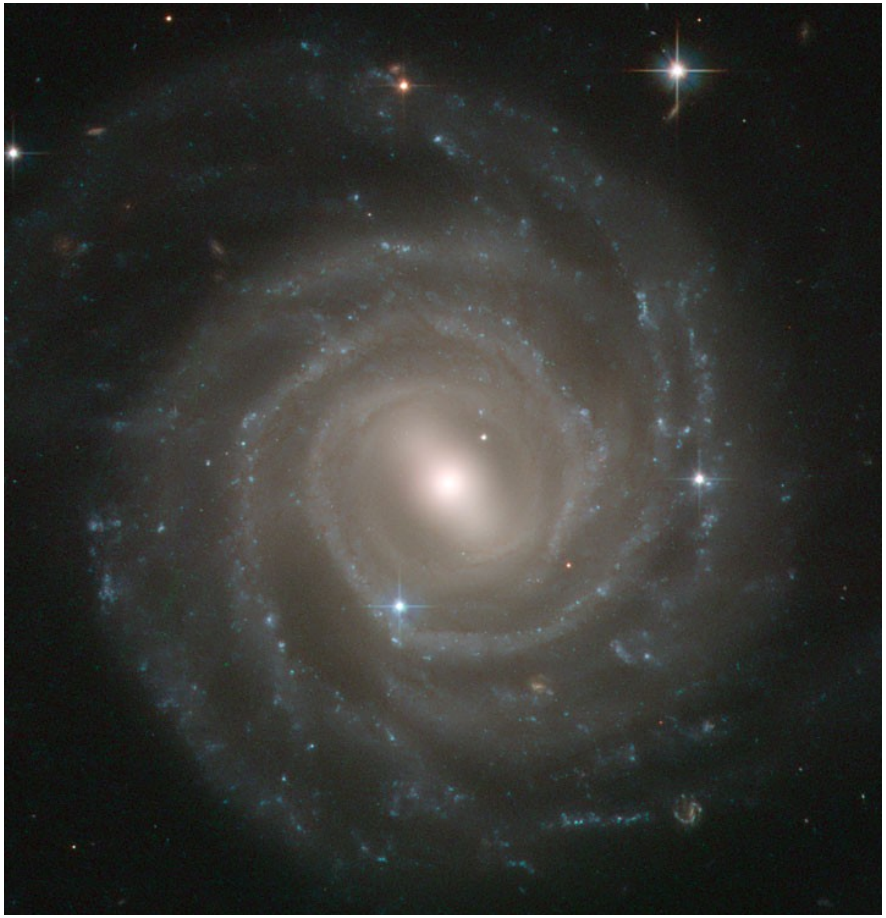
Introduction

- 30-60% of disc galaxies in the local universe host a bar in their center (Barazza et al. 2008, Nair & Abraham 2010, Laine et al. 2016)

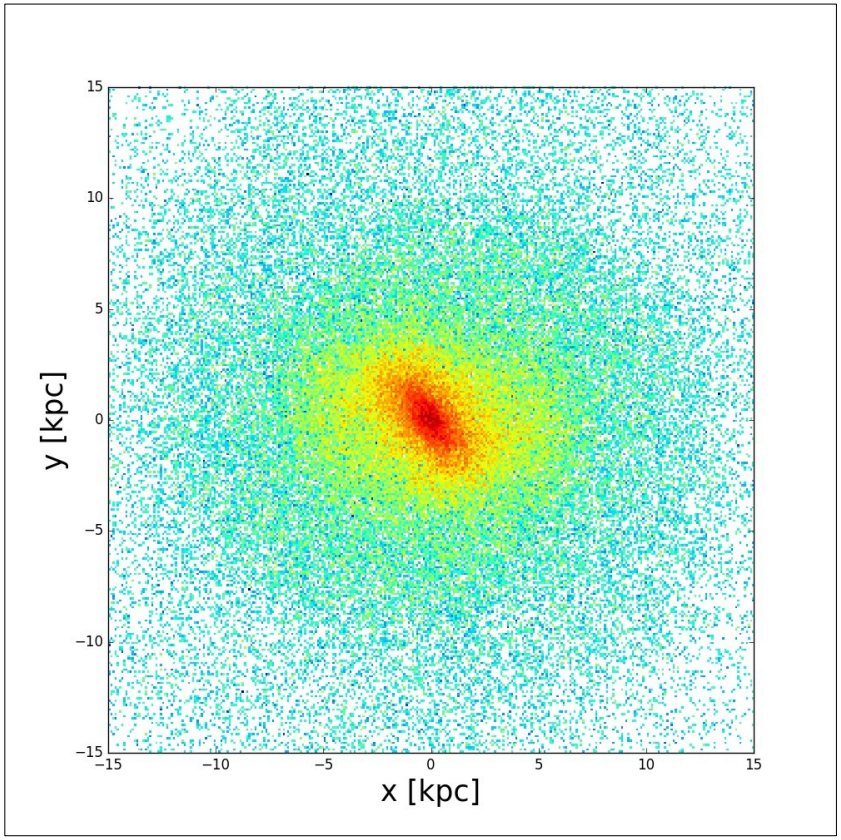
- Bars can be formed in situ, or triggered by interactions with other galaxies: Tidal Bars

- Illustris : high resolution hydronymical cosmological simulation : $(106\ \mathrm{Mpc})^3$, ~18 billion particles (Volgelsberger et al. 2015)

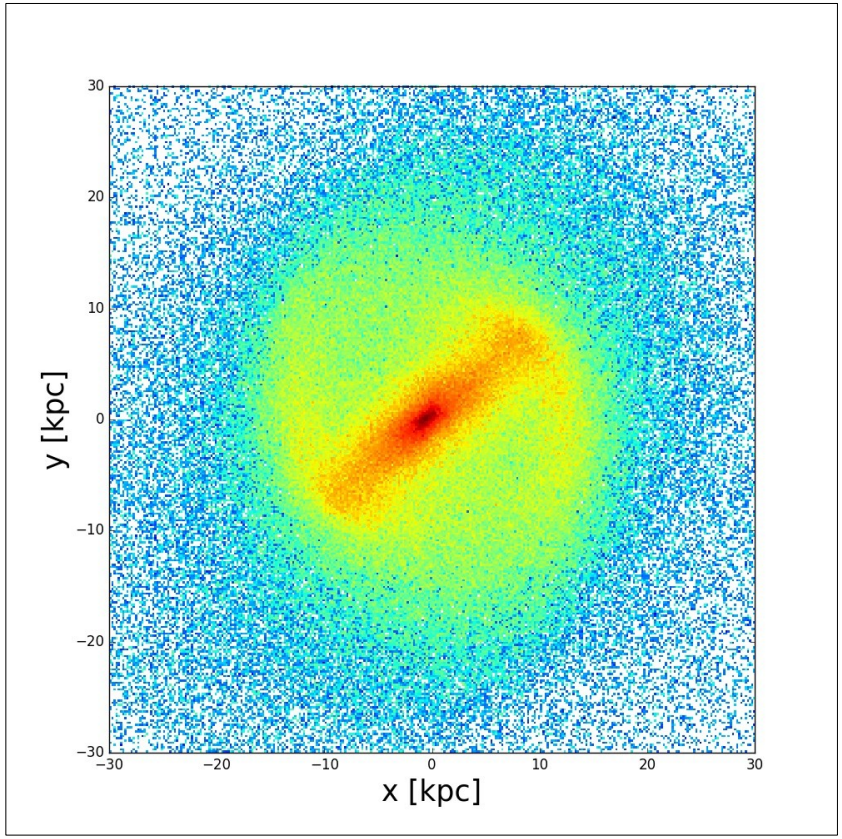


UGC 12158, Hubble Space Telescope

Bars in Illustris galaxies



Weak Bar



Strong Bar

Bars in Illustris galaxies

- Definition of bar strength :

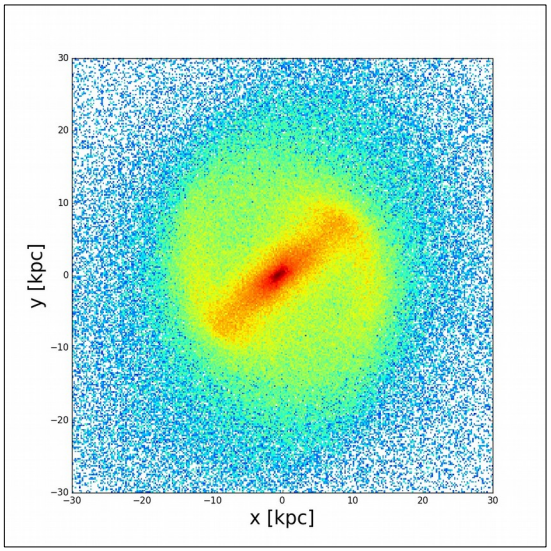
  Fourier moments:

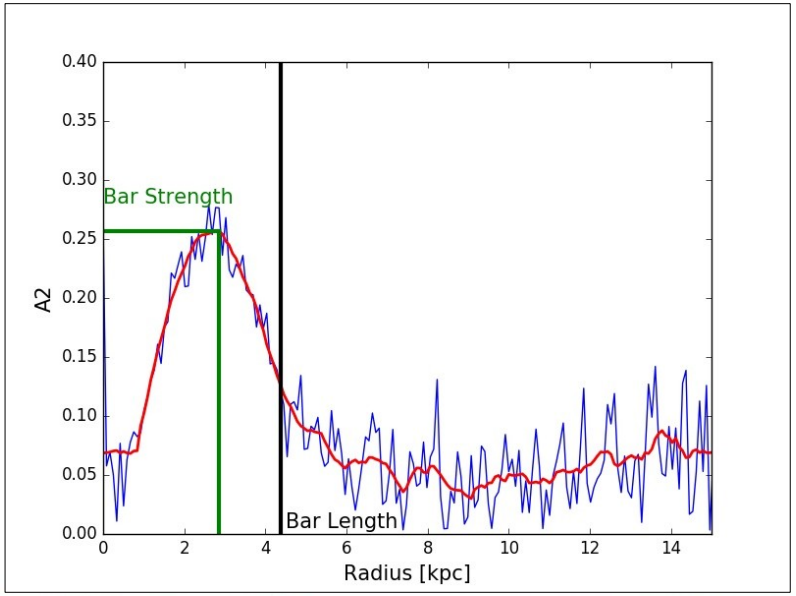
  – $a_m(R) = \Sigma_i M_i \cos(m\phi_i)$

  – $b_m(R) = \Sigma_i M_i \sin(m\phi_i)$

  Amplitude of m=2 component A_2: $A_2(R) = \frac{\sqrt{a_2^2 + b_2^2}}{a_0}$

  → Bar Strength: $A_{2,max} = \max(A_2)$





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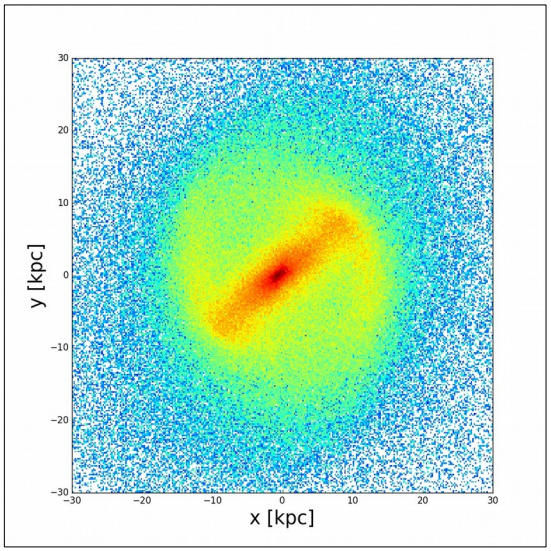
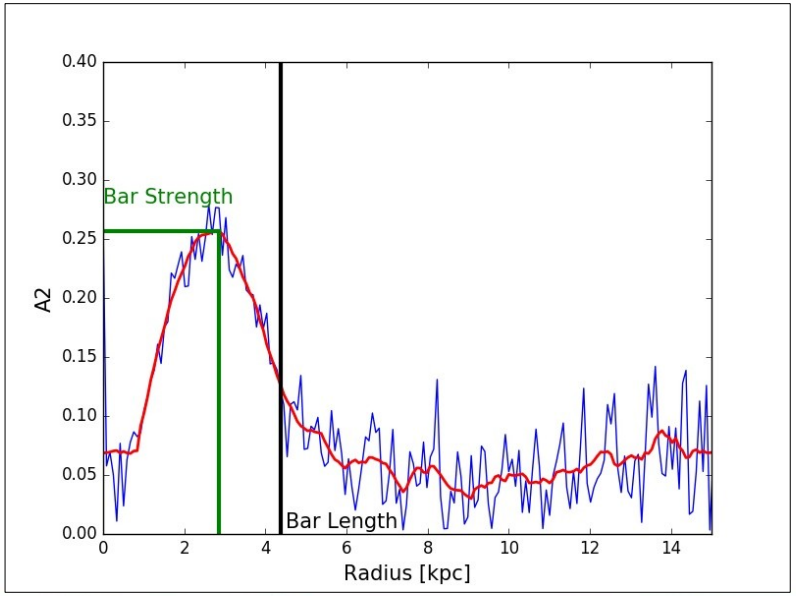
- Presence of a Bar if $A_{2,max}$>0.15:

  → ~26% of bars in local disc galaxies

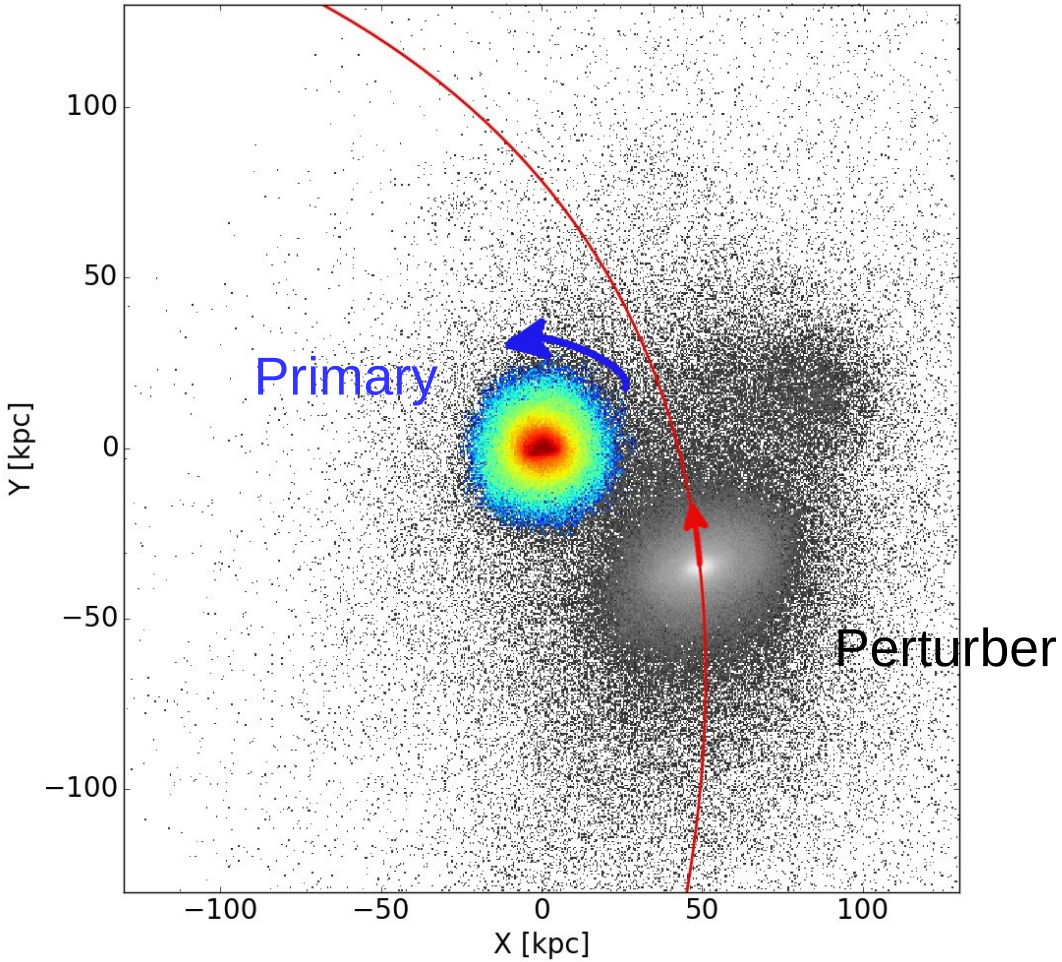
  → bar fraction ~ constant up to redshift 1

  → bar fraction increases with total mass





Bars and interactions



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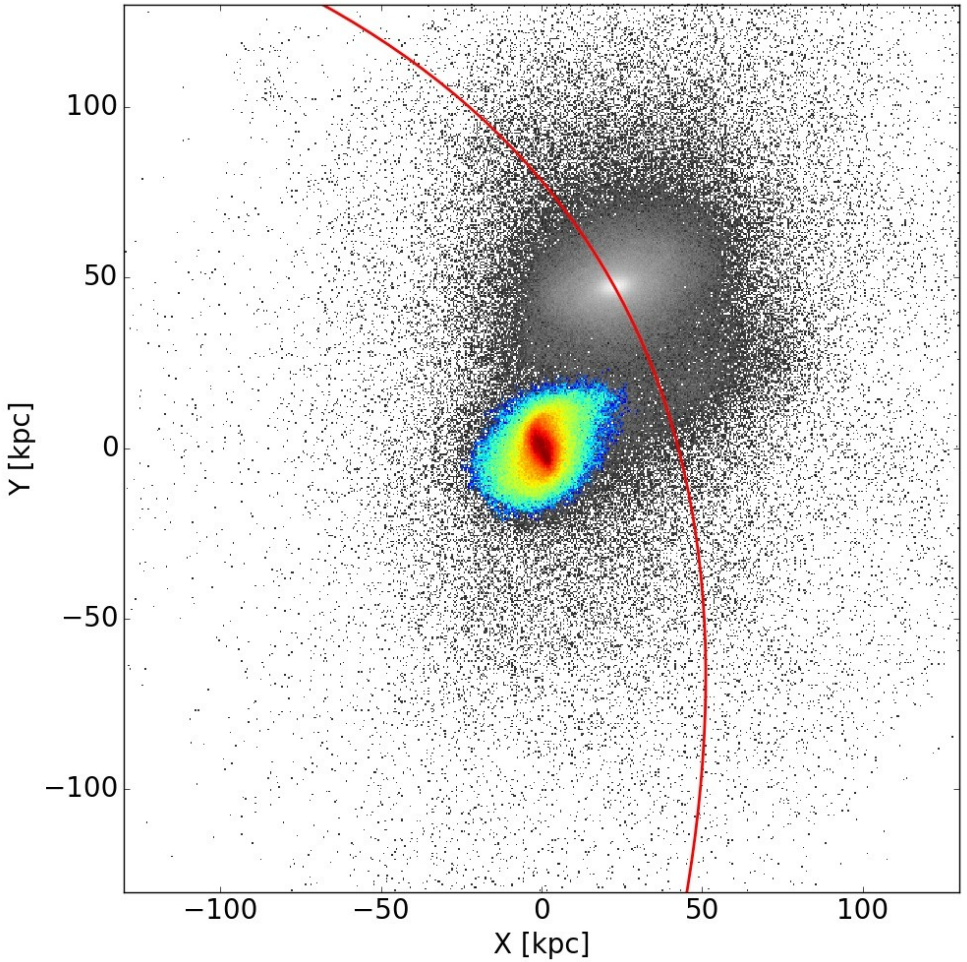

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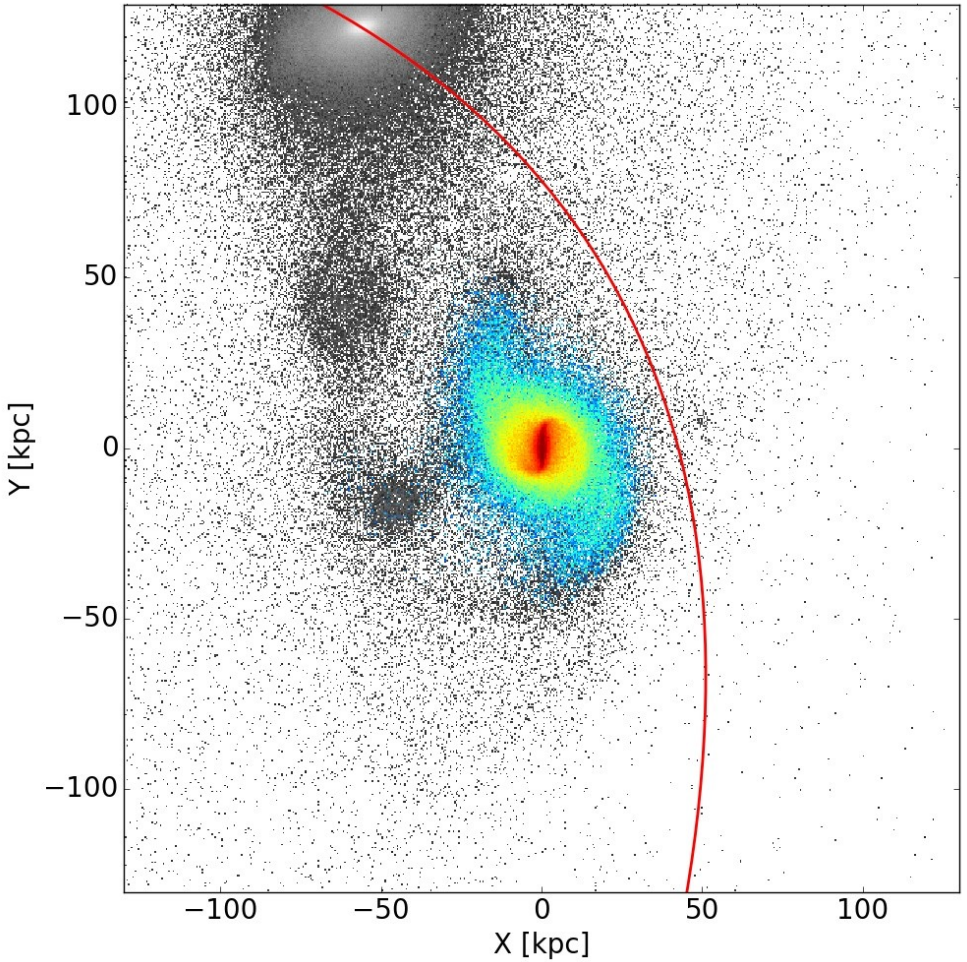

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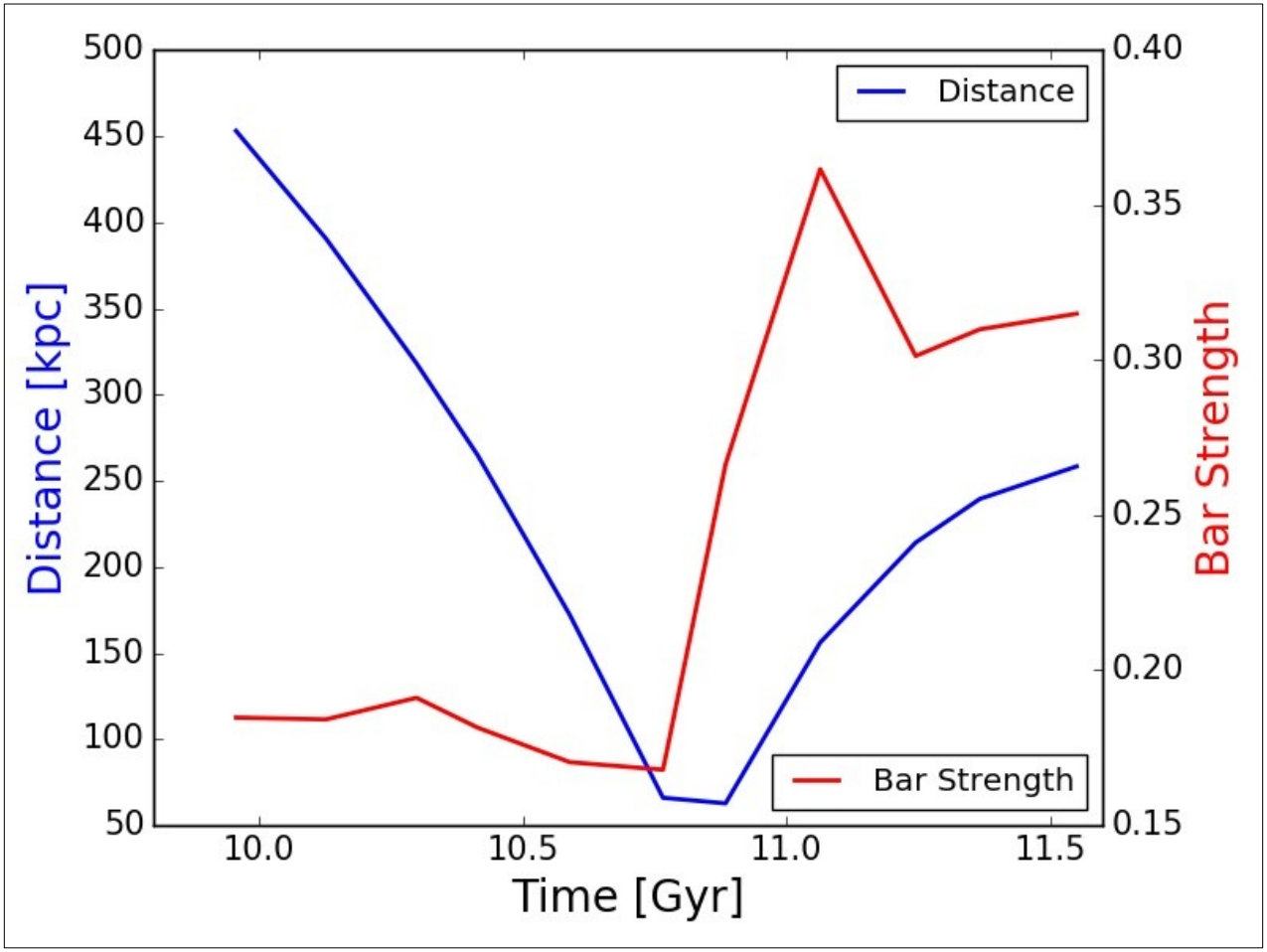
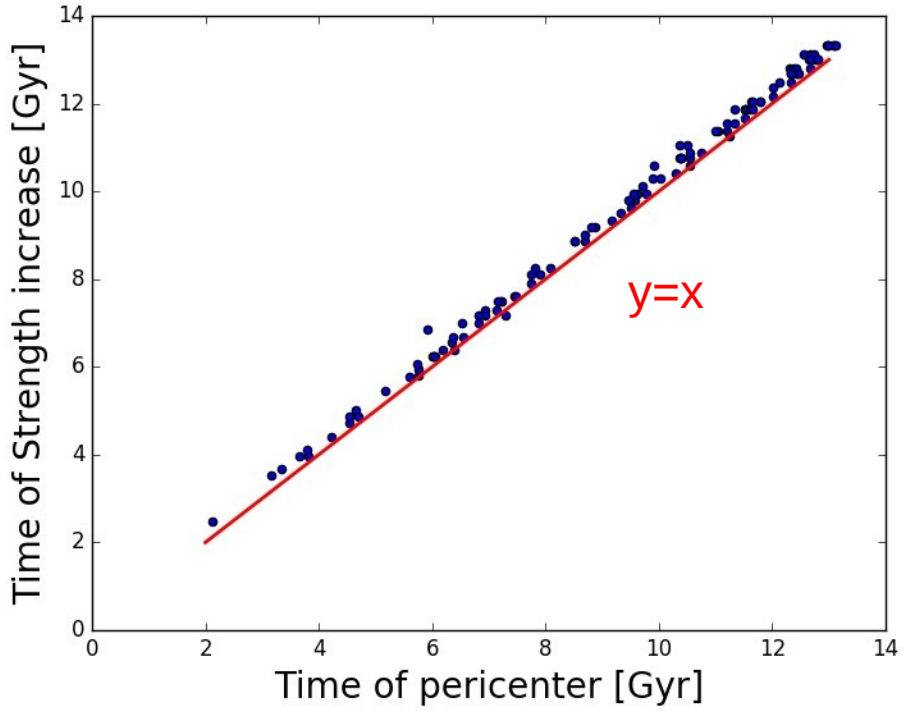


Bars and interactions

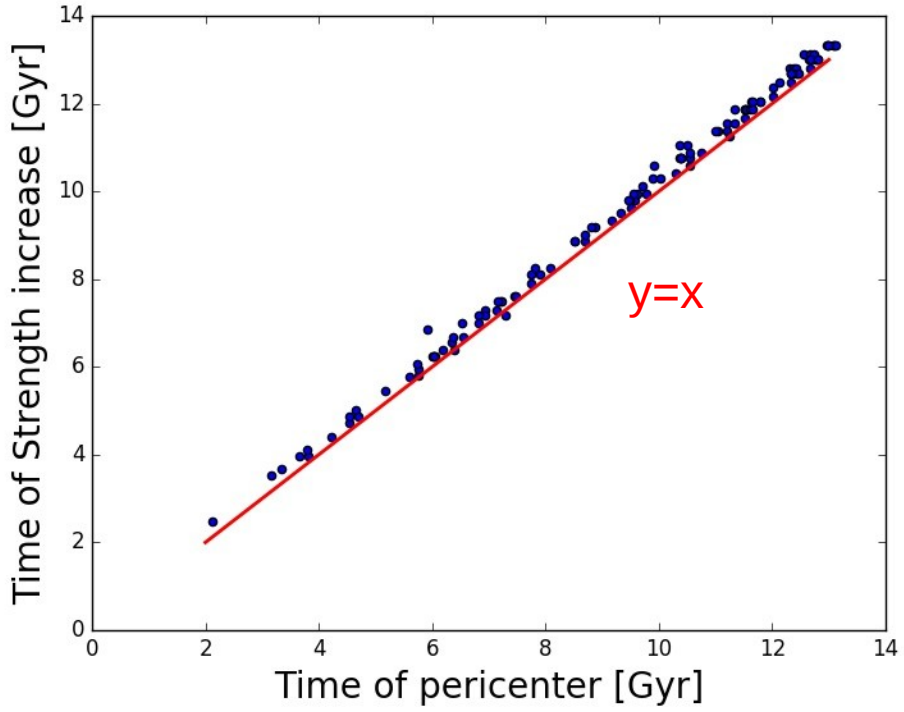
- Sample of 122 galaxies undergoing a fly-by interaction

- Bar strength increase happens right after the pericenter passage (0.29±0.14 Gyr)



Bars and interactions

- Sample of 122 galaxies undergoing a fly-by interaction
- Bar strength increase happens right after the pericenter passage (0.29±0.14 Gyr)
- In case of a pre-existing bar, the fly-by can:
  - Increase the bar strength
  - Decrease the bar strength
  - Have no effect
- Which parameters are responsible for these differences?

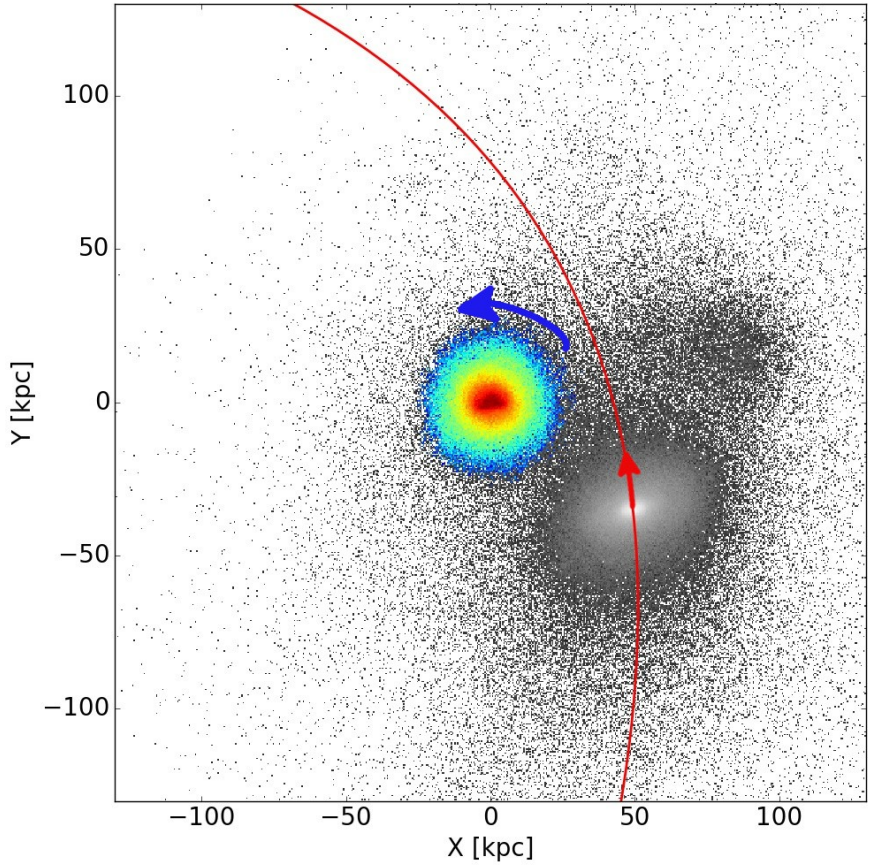


Bars and interactions
Orbital Angle

- Orbital Angle θ: Angle between the orbital plane of the encounter, and the primary disc plane:
  - Prograde encounter:

    cos(θ) ~ 1
  - Retrograde encounter:

    cos(θ) ~ -1



Prograde case

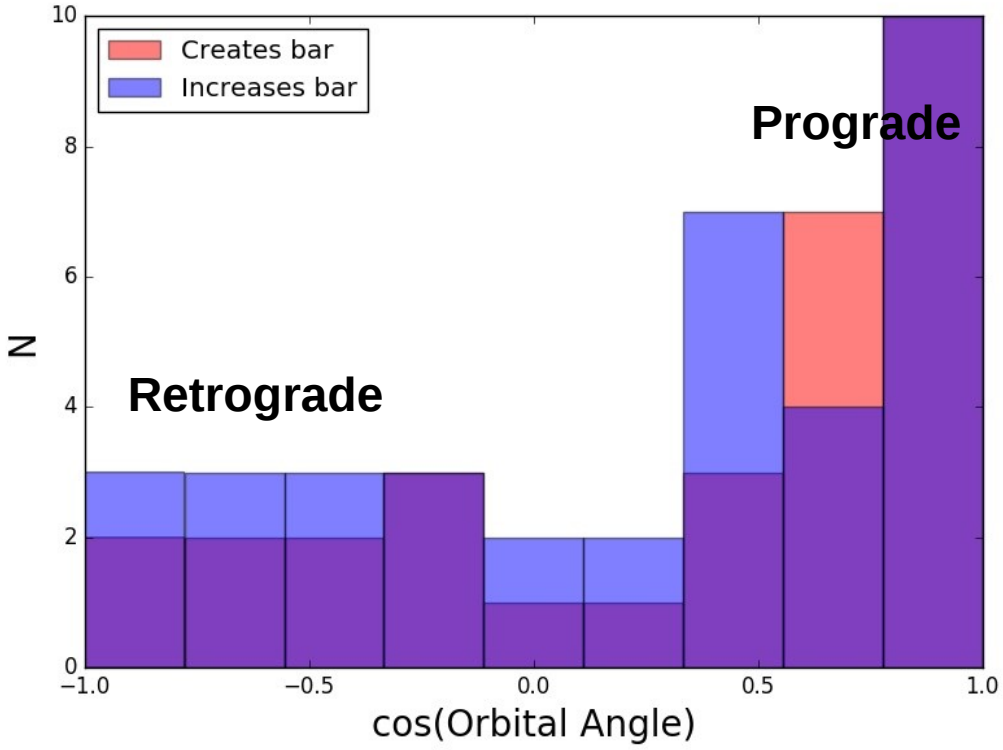
Bars and interactions
Orbital Angle

- Orbital Angle θ: Angle between the orbital plane of the encounter, and the primary disc plane:
  - Prograde encounter:

    cos(θ) ~ 1
  - Retrograde encounter:

    cos(θ) ~ -1

- Mostly pro-grade encounters create bars, or increase the bar strength

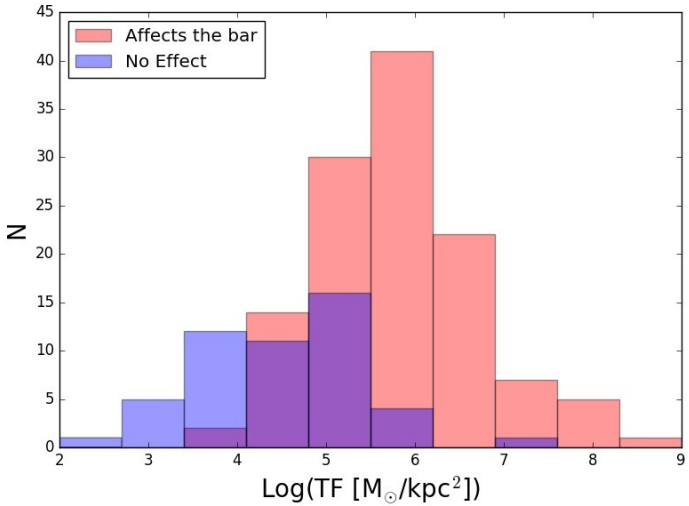


Bars and interactions
Tidal Force

- Strength of the interaction: Tidal Force (Lokas et al. 2016):

$$TF = \frac{R_1 * M_2}{D^3}$$

R1: scale-length of primary galaxy
M2: mass of the perturber
D: distance between the 2 galaxies



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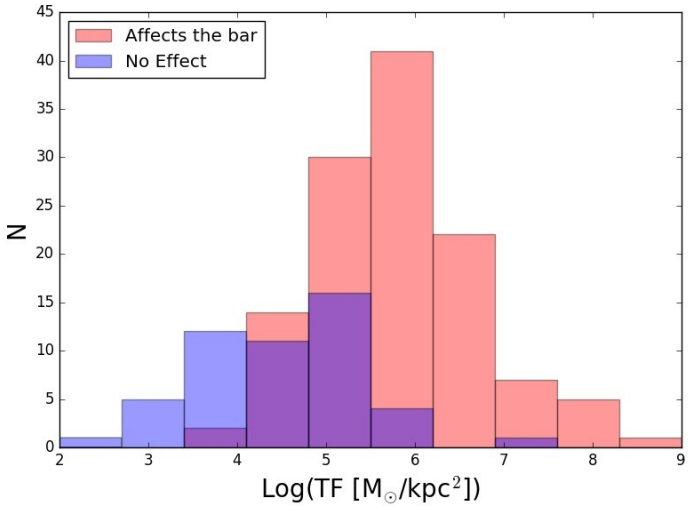
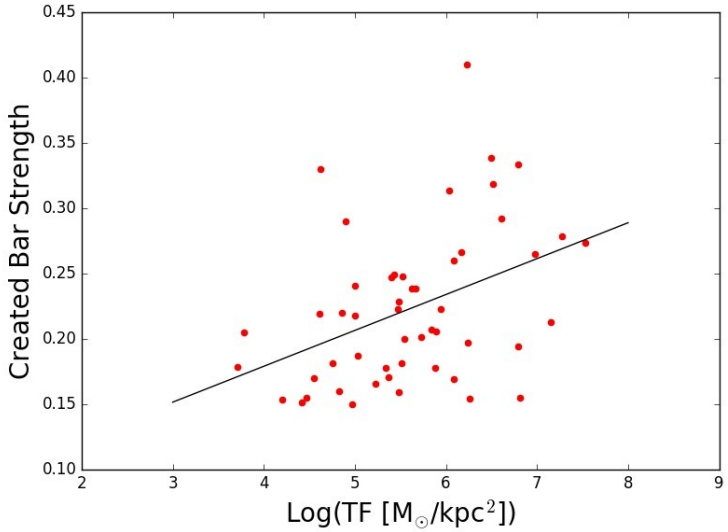
- The stronger the interaction, the stronger the created bar: *weak* correlation
- Many other parameters can come into play: orbital angle, bar position angle, primary galaxy mass...





Conclusion

- Fraction of barred galaxies in Illustris is in the lower values of observations, increases with galaxy mass
- Tidally induced bars: bar is created right after the pericenter passage of an encounter
- Prograde orbits is the preferred way to create a bar or increase the bar strength
- The stronger the interaction, the stronger the created bar strength, but many other parameters can come into play

Thank you!